Vermitech-A Potential Technology for Soil Management and Productivity

Sundaravadivel, S and Sultan Ismail
Institute of Research in Soil Biology and Biotechnology, The New College, Chennai, India.

Abstract. Chemical inputs have made soils unproductive. The importance of organic inputs and the impact of soil fauna specially the earthworms are discussed with reference to reclamation of sandy soils, sodic soils, and cultivation of paddy.

Keywords: Bioremediation, Difficult soils, Earthworms, Organic inputs, Productivity.

1. Introduction

1.1 Soil

Soil is defined as "a collection of natural bodies synthesised in profile form from a variable mixture. It is a chief land resource and component of the terrestrial ecosystem. It is a dynamic natural body of mineral and organic constituents. The dynamic nature is due to the activity of micro and macro organisms supported by availability of organic matter. Soil structure and porosity are much influenced by the activities of all these soil organisms" (Juma, 1993). A vast number of organisms live in the soil. These organisms that include the bacteria, fungi, mites, snails, beetles, millipedes, wood lice, springtails, nematodes, slugs, insects, actinomycetes, earthworms and enchytraeid worms engineer a myriad of biochemical changes as decay of organic matter takes place. Perhaps the most significant contribution of the soil fauna and flora to higher plants is that of organic matter decomposition. Among the organisms, which contribute to soil fertility, the most important are the earthworms. The term "fertility" refers to the inherent capacity of a soil to supply nutrients to plants in adequate amounts and in suitable proportions. Productivity is related to the ability of a soil to yield crops.

1.2 Earthworms

Ecologically earthworms are classified into epigeics (those that live above the mineral soil surface) *(eg : Eisenia foetida, Eisenia andrei, Eudrilus eugeniae Perionyx excavatus* and *Drawida modesta*), anecics (live in burrows in mineral soil layers which drag leaves into burrows *(eg: Lumbricus terrestris, Lampito mauritii* and *Octochaetona serrata)*, and endogeics (live inside the soil and feed on soil organic matter) *(eg: Octochaetona thurstoni)*.

Earthworms have a major role in the breakdown of organic matter and the release and recycling of nutrients. The physical effects of earthworms on soils result from excavation of burrows and production of casts. The casts tend to be much more microbially active than the surrounding soil (Parle 1963 a,b) and have plant nutrients in a form that can be readily utilized. Earthworms in agricultural grasslands and turf ecosystems also have an important role in incorporating surface organic matter into the soil. The role of earthworms in composting organic residues is also well evidenced and documented (Sabine, 1983; Ismail, 1994 a,b,c)

1.3 Organic Farming and Its Significance

Agriculture in India is not of recent origin, but has a long history dating back to the Neolithic age of 7500-6500 BC. Agriculture is the bedrock of Indian economic growth and activity. Most changes in agricultural technology have ecological effects on soil organisms that can affect higher plants and animals, including man. The effects of pesticides, both positive and negative, provide evidence to this fact.

According to Lampkin (1990) organic agriculture or farming is a production system which avoids or largely excludes the use of synthetically compounded fertilizers, pesticides, growth regulators and livestock feed additives. It relies on crop rotations, crop-residues, animal manures, legumes, green manures, off-farm organic wastes and aspects of biological pest control to maintain soil productivity and tilth to supply plant nutrients and to control insects, weeds and other pests. The concept of the soil as a living system that develops the activities of beneficial organisms is central to this definition. In a healthy soil, the biotic and abiotic components comprising organic matter including soil life, mineral particles, soil air and soil water exist in a state of dynamic equilibrium.

This state of soil life and the associated organic transformations enhance the vegetative capacity of the soil and make it resilient to absorb the effect of climatic vicissitudes and occasional failures in agronomic management. Biological diversity is the basis of sustainability in agriculture. Diversity manifests itself at the levels of the ecosystem, farming systems, species, genetic and biological output.

The excessive use of chemical fertilizers characteristic of modern farming creates soil fertility problems and pollution of surface water bodies. When water soluble fertilizers are applied to the soil, a good portion of the added nutrients do not become available to the plants, but are lost either to the atmosphere or to the hydrosphere. In modern farming systems developed in India, since the mid-sixties, as part of the green revolution, the objective has been to maximize production at any cost. Increasing quantities of external inputs such as chemical fertilizers and plant protective chemicals have been used with little reliance on the maintenance of soil organic matter (Thampan, 1995).

In organic agriculture, importance is assigned to the efficient use of water resources by avoiding over-irrigation, minimizing runoff losses and adopting measures of on-farm conservation of rain water. When the soil is tilled frequently it loses its granulation and suffers from compaction. These changes cause a reduction in the rates of water entry into the soil. The exposed soil without the protective cover of grasses and other plant residue becomes vulnerable to both water and wind erosion.

In organically managed farms, the qualities of plant and animal products are much better in terms of nutrition, taste and keeping quality. This has a direct influence on the health of society. It is now known that organically produced vegetables and fruits contain comparatively low concentrations of nitrate nitrogen and trace metals like cadmium. Nitrate accumulation in drinking water as well as in food is caused mainly by the continuous addition of nitrogenous fertilizers to soils, which are poor in organic matter status. Nitrates in foods are easily converted into nitrites, which in combination with amines and certain fungicide residues lead to the production of carcinogenic compounds.

Venkataramani (1992) has published the precise account of the pesticide use pattern in India. Cotton, which accounts for just 5% of the cropped area, consumes about 50-55% of the pesticides. Rice grown over 24% of the cropped area uses about 18%, vegetables raised on 3% of the area uses about 14%, plantation crops covering 2% of the area use about 7%, and cereals, millet, and oil seeds extending over 58% of the area use around 7%, sugarcane uses 2% and other crops occupying over 6% of the area consume 2%.

Though the pesticide use in India is only 3.75% of the total quantity consumed in the world, about half of the world's pesticide poisoning cases and almost three quarters of the deaths take place in India.

1.4 Earthworms in Organic Agriculture

Earthworms can be called as biological indicators of soil health, for soils with earthworms definitely support healthy populations of bacteria, fungi, actinomycetes, protozoans, insects, spiders, millipedes, and a host of other organisms that are essential for sustaining a healthy soil (Ismail, 1997).

Earthworm casts get converted into stable soil aggregates by the action of gums that result from microbial digestion of their organic compounds (Waksman and Martin, 1939), or by the binding effect of fungal hyphae (Parle, 1963 a,b). There are also reports that certain metabolites produced by earthworms may be responsible to stimulate plant growth (Gavrilov, 1962; Neilson, 1965).

In-situ management of earthworms for soil fertility is always beneficial. To maintain earthworms in the soil, moisture and organic matter requirements are essential. Many such traditional and ecofriendly technologies, which are innovative, must be implemented to produce food free from chemicals, toxic substances and residues. One among the many such technologies, which can be used in all spheres, is "VERMITECH" (Ismail, 1994, a,b,c; 1995 a,b) using native or indigenous earthworms for converting organic waste into valuable vermicompost, and in soil management.

1.5 Present Investigation

The present investigation deals with the role of earthworms in compost production from several organic wastes or inputs as well as its application in soil remediation and plant productivity. These experiments have been carried out in three phases.

Phase 1: Mass production of vermicompost and its application in sandy soils for growth and regulation of *Cynodon dactylon* at odhiyur, Tamilnadu, India.

Phase 2: Application of earthworms in sodic soils under test conditions, to study their role in sodic soil bioremediation at Shivari Farms, of the Uttar Pradesh Land Development Corporation (UPLDC), near Lucknow, Uttar Pradesh, India.

Phase 3: Application of vermicompost in paddy fields, to study the selected pedofaunal density in organically treated soils in contrast to chemically treated plots at Urappakkam, near Chennai, Tamilnadu, India.

2. Materials and Methods

2.1 Odhiyur

The substrate was the unproductive beach sand; and dominant flora comprises of *Casuarina equisetifolio* and *Borassus flabellifer*.

Large scale production of vermicompost involves more number of vermipits. One hundred and sixty (160) pits (6 m x 3m x 1 m each) were dug out and prepared as per "VERMITECH" pattern, and *Lampito mauritii* and *Octochaetona serrata* species of earthworms were inoculated (Plate 1).

Organic inputs for Vermicompost Production
Pressmud (filter presscake from the sugar industry), poultry droppings, groundnut pods, dried leaf litter of *Mangifera indica, Anacardium occidentale,* grass clippings, crocodile dropping, farmyard manure, fish waste and vegetable waste were collected and transported to the site for the large scale production of vermicompost. Leaf litter and hay provide additional carbon while cattledung and other such inputs provide rich sources of nitrogen to the earthworms.

Vermiwash Units
Vermiwash is a liquid fertilizer which is collected after it passes through a layer of soil, with earthworms in it (Ismail, 1997). The nutrients in vermiwash are in a readily available form. The coelomic fluid, mucus, nitrogenous excreta and castings of earthworms synergise with each other enabling uptake of these available nutrients in a profusely rapid manner. Totally 59 vermiwash units were set up at the site for application to grass.

Preparation of Plots
Sand was dug to about 10-15 cms and coirpith compost, vermicompost, burnt ricehusk (4:4:1) were amended into it as basal dressing. Coirpith acts as an effective soil amendment as it retains considerable amount of moisture and functions as a mulch.

Biocontrol Agents
To check attack against pests, neem *(Azadirachta indica)* products like neem cake powder, neem gold, Nimbicidine and Neem Azal and extracts from leaves of *Vitex negundo* and *Pongamia glabra* were used as sprays using different combinations along with vermiwash to control pests.

Total Area of Grass Grown
Grass was grown totally on twenty five acres (10 hectares) of land on the site. The sandy soils of odhiyur have a very low organic carbon content (0.53 - 0.57%), nitrogen (0.01%), phosphate (0.09 - 0.10%) and potassium (0.03 - 0.04%). Such sandy soils were applied with

vermicompost (5 tones per ha) for reclamation, as compost has the ability to not only offer nutrients to the soil but also is capable of holding nutrients and moisture, facilitating the growth of plants. Compost increases soil organic matter, total nitrogen and soil microbial flora.

Sodic Soil

Experiments were planned and initial earthworm cultures were started using sodic and gypsum treated sodic soils. Sodic soils contain exchangeable sodium ion in quantities which adversely affect the growth of most plants. These soils may also contain appreciable quantities of salts capable of alkali hydrolysis, like sodium carbonates.

In the hydrolysis of exchangeable cations, H^+ is inactivated by exchange adsorption in place of Na^+. The displaced Na^+ does not combine with or inactivate OH^- ions which results in an increase in the OH^- ion concentration and consequently the increased pH.

Setting Up of Culture Boxes

Twenty-three wooden boxes were set up as per vermitech pattern as follow:

a. *Lampito mauritii* in sodic soil (LSS) (eight boxes).
b. *Perionyx excavatus* and *Lampito mauritii* in sodic soil (PLSS) (eight boxes).
c. *Perionyx excavatus* and *Lampito mauritti* in non-sodic soil (PLNS) (seven boxes).

Inoculation of Earthworms

Into each of these boxes were inoculated five numbers of *L. maruitii* and *P. excavatus* as the case may be. Straw (500 gm) and Cattledung (1000 gms) were applied on the top. pH of the sodic soil used was between 9 and 10. Pressmud (250 gm) was applied to all the culture boxes after 15 days. Three boxes at random were taken after 30 days and after removing the surface compost layer, were dismantled for estimating earthworm numbers.

Culture Tanks

To multiply earthworms (Vermiculture) seven (7) culture tanks (each 110 cms x 90 cms x 50 cms) were constructed in a culture room. In each of the culture tanks were inoculated about 25 numbers of *P. excavatus* and *L.mauritii* and covered with cattle dung and hay or straw.

2.3 Urappakkam

Field study was conducted in twenty five (25) plots of the six acres (2 hectares) organic farm. Initial survey was done to assess earthworm numbers, microarthropod density and soil quality.

Paddy Experiment

Paddy *(Oryza sativa)* (variety: Ponni) seeds (six months duration crop) weighing 300 kg were sown in six acres (2 hectares).

Transplanting

After thirty five (35) days of growth in the nursery the seedlings were transplanted to the mainfield. For convenience, two plots each measuring (15m x 15m) were taken for experimental study.

Earthworm Population

Earthworm density (nos/0.1 sqm) was estimated before, during and after Paddy cultivation.

Growth and Yield

During growth of plant, the number of tillers, height of the crop, panicles per hill, length of panicle, number of grains per panicle, number of chaffs per panicle and weight (gm/1000 grains); yield (kg/acre) and duration of crop (days) and harvest details were recorded.

Extraction of Microarthropods

The extraction of microarthropods from the soil samples as well as from the crop residues (each 500 gms) was done using a series of modified Tullgren funnels set up in the laboratory.

3. Results

Results show that application of organic manure increases the amount of both organic carbon and total nitrogen in the soils, the increase and change in C:N ratio being dependent on the source of manure and the soil type as also reported by Ismail *et.al.,* (1998).

Based on these applications both varities of grasses (Greenlespark and Tif Dwarf) exhibit identical growth patterns with a desired density of shoot lengths varying from 2.59-3.70 cms. The earthworm population increases from 100 numbers at introduction in each composed pit to 2000 earthworms per pit.

In the plots of the organic farm, the soils showed a positive correlation in EC, OC, OM, TKN, P_2O_5 and K_2O with the stages of the experiment (before, during and after Paddy harvest).

In the chemical farm there exists a positive correlation in OC, OM, P_2O_5 of the plots with the three phases of the experiment, while EC, TKN and K_2O show inverse correlation.

A comparative study of plant growth in chemical and organic farms is shown in Table 1.

Table 1: A comparative study of plant growth in a chemical and an organic farm

Chemical Farm		
Length of Panicle (cms)	Number of Grains	Number of Chaffs
14.63 ± 2.42	54.875 ± 15.38	5.525 ± 2.428

Organic Farm		
Length of Panicle (cms)	Number of Grains	Number of Chaffs
16.016 ± 4.807	58.520 ± 18.637	7.291 ± 2.349

4. Discussion

4.1 Sandy soil

Application of compost on surface soils may provide organic matter. But the presence of anecic organisms is essential to create channels in the soil for effective soil reclamation (Ismail, 1997).

The nutrient condition of sandy soil is poor; moreover nutrients applied to sandy soils through inorganic fertilizers get leached out. Organic inputs in the form of vermicompost and mulch assist in the passive inoculation of earthworms. Earthworms also promote comminution of sand which helps in the retention of nutrients enabling plant growth. Addition of vermicompost has proved efficient in growing Greenless park and Tif dwarf grass varieties on sandy soils.

4.2 Sodic soil

To combat such difficult soils, "Vermitech" has now proved most effective in pilot experiments comprising culture tanks. Combinations of epigeic and anecic varieties of earthworms *(P. excavatus* and *L. maruitii)* have been cultured in sodic soils in tanks and boxes.

Results indicate that sodic soil treated with earthworms, especially a combination of *P. excavatus* and *L. mauritii,* shows a higher organic carbon content (4%) and a relatively high nitrogen content (0.4%). The C:N ratio in reclaimed soils through cultures ranges between 10 and 20. At the end of the experiment (75 days), all parameters (pH, EC, OC, TKN) significantly improved compared to the original sodic soil.

Opening of vermiculture boxes revealed healthy earthworms and the channels created by the anecic earthworms which also promote incorporation of organic matter into the borrows (Plate 2).

4.3 Paddy

Paddy *(Oryza sativa)* is a staple food for the people of the Asian continent. The green revolution pioneered chemical inputs in the form of synthetic fertilisers and pesticides for improving Paddy production in India.

Traditionally Paddy cultivation in India has had inputs in the form of Farmyard manure, cattledung compost, green manure and application of botanical pesticides like neem *(Azadirachta indica)*, Pongam *(Pongamia glabra)* and nochi *(Vitex negundo)*. The traditional Paddy fields in India have relatively smaller units (or) plots and are bordered by ridges around the plots. These ridges specifically called "bunds" have been part of traditional rice cultivation in India (Pai, 1994) as they provide a habitat to soil fauna during water logging as practised traditionally in Paddy plots.

The excess nitrogen, phosphate and potassium during cultivation in the chemical farm is because of chemical inputs.

The organic farm has a stabilizing soil structure. Such stabilization in particular of the organic farm is because of the presence of biological organisms in the soils, that is the soil faunal component, which promotes stabilization of nutrient status through microbial population or as single cell proteins.

This is also facilitated by the earthworm population in the organically managed Paddy fields. The density of *L. mauritii* increased in the plots with organic inputs and is always close to 20/0.1 sqm, compared to chemical farms where the population of *L. mauritii* decreases to about 4/0.1 sqm during cultivation because of chemical inputs.

The soils in the plots as well as bunds in the organic farm show higher density and diversity of soil microarthopods. Acari, collembola, dipteran larvae and coleopteran larvae increased in number (Plate 3). In the chemical farm, however, the soil microarthopod population is lower than in the organic farm both in the plots and bunds.

5. Conclusion

Several reports have established the suitability of organic inputs in restoring soil health. Earthworms effect soil structural stability and aggregate stability.

A changeover from chemical to organic inputs into soil improve the soil as a "living soil" by enhancing biotic populations which includes earthworm abundance and biomass.

6. Recommendations

Compost, especially vermicompost, making use of local resources as well as native populations of earthworms is recommended for soil remediation. Earthworms are well established in scientific literature as indicators of soil health and their presence in difficult soils usually marks the beginning of "soil productivity".

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